INTERNATIONAL JOURNAL OF CIVIL ENGINEERING AND TECHNOLOGY (IJCIET)

ISSN 0976 – 6308 (Print)
ISSN 0976 – 6316(Online)
Volume 6, Issue 5, May (2015), pp. 76-84
© IAEME: www.iaeme.com/Ijciet.asp
Journal Impact Factor (2015): 9.1215 (Calculated by GISI)
www.jifactor.com

IJCIET

©IAEME

A COMPARATIVE STUDY OF BS8110 AND EUROCODE 2 STANDARDS FOR DESIGN OF A CONTINUOUS REINFORCED CONCRETE BEAM

[1]T.C. Nwofor, [2]S. Sule, [3]D.B. Eme

[1,2,3]Department of Civil Engineering, University of Port Harcourt,
P.M.B 5323 Port Harcourt, Rivers State, Nigeria

ABSTRACT

In this paper, a comparative study of BS 8110-97 and Eurocode2 for the design of reinforced concrete beam with a particular interest on the area of tension and shear reinforcements required, with the aim of determining which of the two codes provides the most economic design is carried out using Microsoft excel spreadsheet. A six-span continuous beam from the roof of a three storey shopping complex was selected and designed with the aid of a programmed excel spread sheet, taking into account only dead and live loads and assuming all spans to be loaded equally for both dead and live load combination. The self-weight of the beam was taken as the dead load while the live load was assumed to be a unity. The result of the analysis was used to design the beams based on both codes with the aid of a programmed spread sheet. The percentage difference between the areas of steel required by the two codes was calculated with the BS 8110 code results as the control values. The average percentage difference for all spans was found to be about -3.08%, indicating that the Eurocode2 requires less amount of reinforcement at the spans. The average percentage difference for all supports was found to be about -2.83%, indicating that the Eurocode2 requires lesser amounts of reinforcements at supports. The average percentage difference of the required ratio of area of shear reinforcement to spacing was about -61.90% indicating that the BS8110 requires more shear reinforcement than the Eurocode2.

Keywords: BS8110-97, Eurocode 2, Tension Reinforcements, Shear Reinforcements, Economic Design.

1.0 INTRODUCTION

The structural design of most buildings worldwide is based on national or international codes of practice. These guide the engineer in the general appraisal of the overall structural scheme, detailed analysis and design. Codes of practice are basically guides drawn up by experienced

engineers and a team of professionals, and they provide a framework for addressing issues of safety and serviceability in structural engineering design. In the African continent, national codes of practice have been primarily derived from the British standard BS8110-1997 [1] and its predecessors. In several countries the British standard has been employed almost exclusively with the exception of variation of nationally determined parameters. In the last three decades however, an alternative set of codes to replace the British and other European national standards has been developed termed the Eurocodes (ECs). The Eurocodes are a new set of European structural design codes for building and civil engineering works. The Eurocodes have been introduced as part of the wider European harmonization process and not just simply to directly replace any national codes [2-8]. In the design of concrete structures, the relevant parts of the codes are EC0: Basis of structural design, EC1: Actions on structures and EC2: Design of concrete structures. The aims of these Eurocodes are collectively to provide common design criteria and methods to fulfil the specified requirements for mechanical resistance, stability and resistance to fire, including aspects of durability and economy. Furthermore they provide a common understanding regarding the design of structures between owners, operators and users, designers, contractors and manufacturers of construction materials.

Nowadays, Eurocodes are being introduced and applied for design of concrete structures but still not yet widely used in Nigeria. The Eurocodes are intended to be mandatory for European public works and likely to become the standard for the private sectors both in Europe and the world at large. Prior to the emergence of the Eurocodes, the British standard codes of practice has been in use to serve the same purpose the Eurocodes were intended and it begs a lot of questions as to what the differences are in construction infrastructure. The purpose of this work is to find out significant differences (if any) between the BS 8110 and the Eurocode2, taking the design of a reinforced concrete beam as a case study of the comparison.

Structural design refers to the selection of materials, size, type and the suitable configuration that could carry loads in a safe and serviceable fashion [9]. Design may also be described as a process through which the engineer determines the type, size and materials used through a meticulous calculation until detailed drawing is produced [10-11]. Design is involved at all elements of the building such as slab, beam, column, foundation, roof etc. In the design of reinforced concrete Beams, considerations are made for bending moment, shear force, cracking and area of reinforcement.

Usually in Nigeria, the design of structures is guided by the use of British Standard, (BS 8110). BS 8110 is a British Standard for the design and construction of reinforced and prestressed concrete structures. BS 8110 is based on limit state design principles. Although used for most civil engineering and building structures, bridges and water-retaining structures are covered by separate standards (BS 5400 and BS 8007 respectively). In this study, excel spreadsheet is used to compare the results of the two design codes. The algorithm is simple and it caters for the errors that may be incurred in the manual design.

2.0 Methodology

The structure chosen for the present study is a continuous beam of six equal spans, taken from the roof of a shopping complex.

2.0 Materials and Method

2.1 Dead and Imposed Loads

In the beam design, commonly used parameters such as imposed loads and concrete grade were made uniform for both BS8110 and Eurocode2. Varied parameters were mainly those based on theories of the codes such as the equations governing flexure at the ultimate limit state and shear.

The dead loads are taken as the self-weight of the structure and are gotten by multiplying the cross-sectional area of the beam by the unit weight of concrete for both codes. The unit weight of concrete as per BS8110 is given as $24KN/m^3$, while that for Eurocode2 is $25KN/m^3$. The Differences in these principles might result in differences in the amount of load a common member dimension could carry, be it at service or the ultimate limit state. Consequently, the amount of reinforcement required might also be affected.

In this study, prismatic beam cross-sections were adopted because both Eurocode2 and BS8110 show no substantial difference between preliminary span/effective depth ratios for beams. Table 1 below shows the basic span/effective depth ratios of a rectangular beam for both codes.

Table 1: BS8110 and Eurocode2 basic span/effective depth ratios for rectangular beams

Support conditions	BS8110-1997[3]	Eurocode 2 [12]
Cantilever	7	7
Simply supported	20	18
Continuous	26	25
End spans of continuous beams	–	23

2.2 Ultimate Design Load

In addition to the varied parameters mentioned above, the ultimate design load formulae in both codes are of great importance in the rate of loading on the structure. Consequently, the moments and shear forces acting on the structure may be affected as a result of these variations in loading. At the ultimate limit state, the maximum design load can be estimated by using equations (1) and (2) for BS8110 and Eurocode2 respectively.

$$w = 1.4gk + 1.6qk \quad (1)$$

$$n = 1.35gk + 1.5qk \quad (2)$$

Where:

gk and qk are dead loads (including self-weight) and imposed loads respectively. 1.4, 1.6 and 1.35, 1.5 are all partial safety factors for loads for BS8110 and Eurocode2 respectively.

In this study, the load combination chosen is on the basis of all spans loaded equally i.e. 1.4Gk +1.6Qk for all spans.

2.3 Structural Analysis

The moments and shears on the beam were obtained from structural analysis carried out using hardy cross moment distribution method as given in the program. Moment distribution is a displacement method of analysis. It is based on the principle of successively locking and unlocking of the joints of a structure in order to allow the moments at the joints to be distributed and balanced.

2.4 Development of Microsoft Excel 2010 Spreadsheet

Microsoft Excel 2010 was adopted and programmed to carry out the computation and analysis of input data. The materials data collected from the codes (BS8110 and Eurocode2) are entered in the first sheet as well as the geometrical properties of the reinforced concrete beam. The data are put in the first sheet named Design Information, and the analysis (moment distribution) is carried out automatically in the next sheet named Analysis. The bending moment and shear force envelopes are placed in the third sheet called Envelopes, while design for flexural reinforcement as well as shear reinforcement are placed in the fourth page. Each of the sheets is discussed as follows:

The design information sheet consist of cells with input data like compressive strength of concrete placed in cell C10, tensile strength of reinforcing steel placed in cell C12 , minimum tensile strength of concrete placed in cell C11, unit weight of concrete placed in cell C13 and concrete cover to reinforcing steel, placed in cell J9. Geometrical properties like span length entered in cells !C25: C30, overall depth of beam entered in cells !D25:D30, and span type (end or interior span) of the beam are also entered in cells !J25:J30. Provisions are also made for loading on adjacent spans of the beam. It is however important to emphasize that the loadings are on a basis of uniformly distributed load (UDL). This is because point loads are seldom encountered on structural designs. The loadings for the six spans shown in the program are factored loads based on the ultimate design load formulae stated in equations (1) and (2).

The structural analysis for the a six-span reinforced concrete beam was carried out based on Hardy cross moment distribution method. The respective distribution factors for each span are gotten by considering the support conditions in the design information sheet. For a pinned outer support, the distribution factor is unity as given in cells B18 and M18; while for intermediate supports, the distribution factor is a sum of the distribution factor to the right and to the left of the supports, as given in cells B9 C9, D9, E9, F9, G9, H9, I9, J9, K9, L9 and M9. The fixed end moments are dependent on the support conditions in cells !M38:M44 in the preceding design information sheet. Distributed moments as well as carry over moments are estimated in turns from each support from cells !A11:A23. Final support moments are estimated after the last distributed moment by summing all the data for moments from cells !A11:A23 to cells !M19:M23 for all the supports. Similarly, the shear forces are estimated in cells B27, C27, D27, E27, F27, G27, H27, I27, J27, K27, L27, and M27. The maximum mid-span moments are computed in the program and stored in cells BC33, DE33, FG33, HI33, JK33, and LM33. A typical view of the analysis sheet is presented in Figure 2..

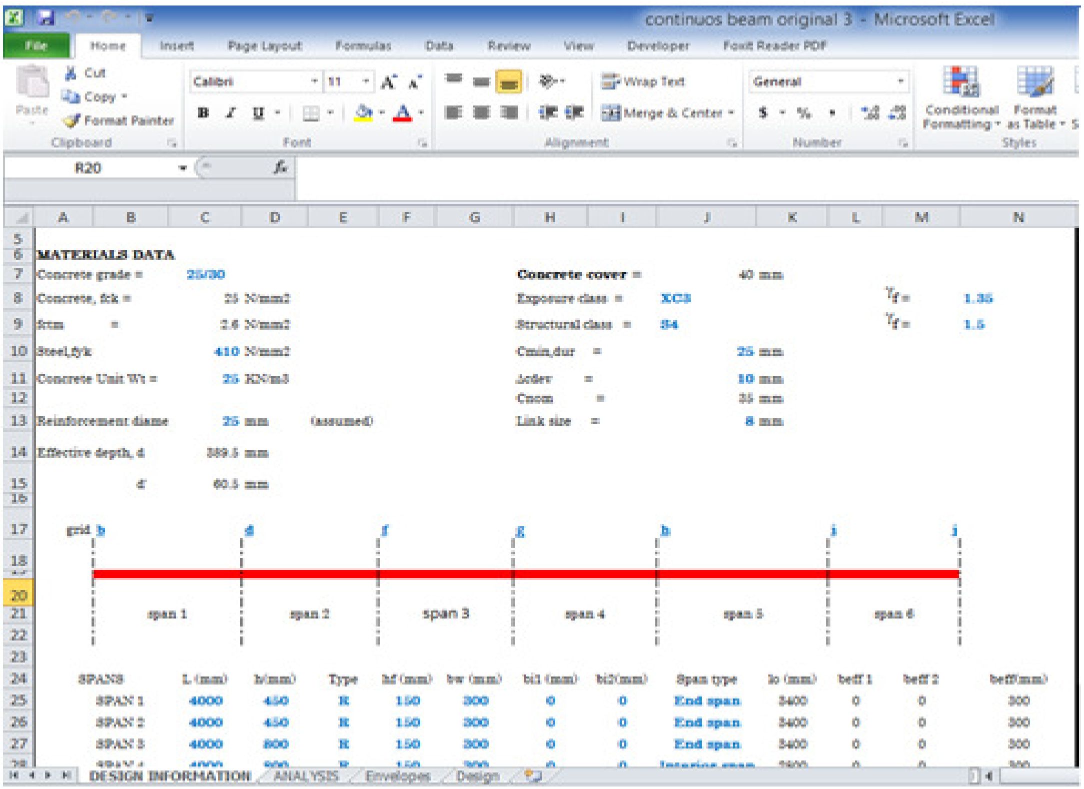
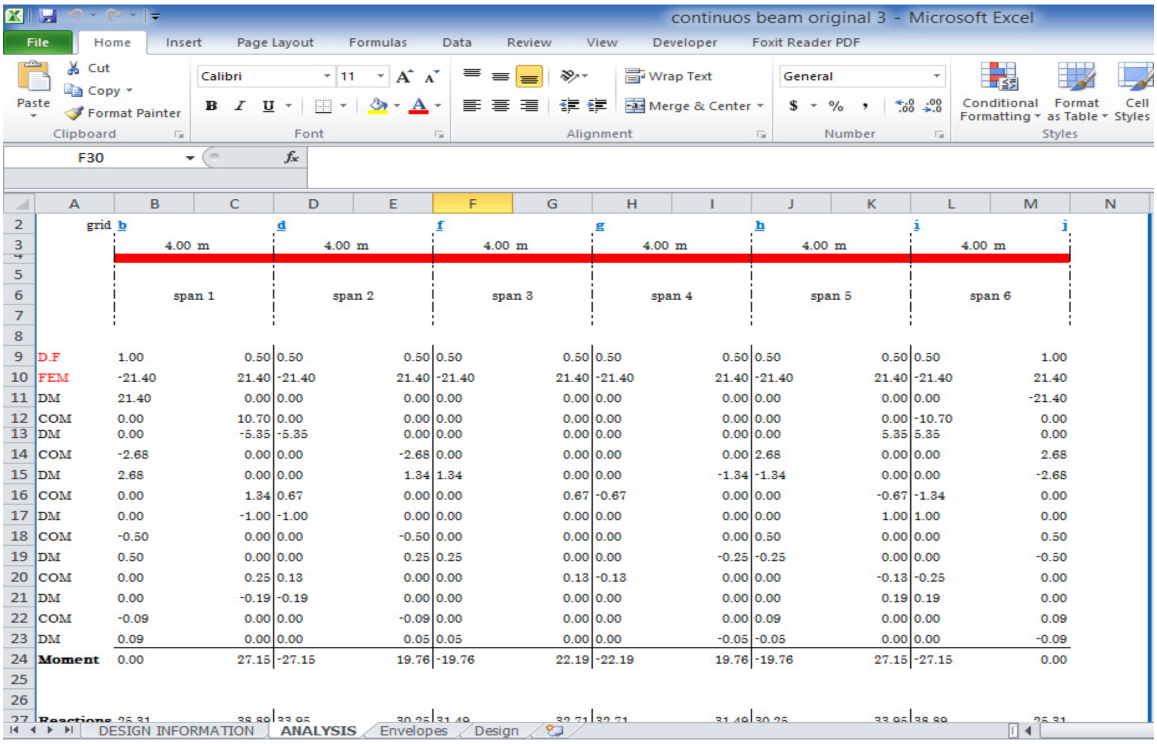


Figure 1: A typical design information sheet (MS Excel 2010)



	b	d	d	f	f	g	g	h	h	i	i	j
D.F	1.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	1.00
FEM	-21.40	21.40	-21.40	21.40	-21.40	21.40	-21.40	21.40	-21.40	21.40	-21.40	21.40
DM	21.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-21.40
COM	0.00	10.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-10.70	0.00
DM	0.00	-5.35	-5.35	0.00	0.00	0.00	0.00	0.00	0.00	5.35	5.35	0.00
COM	-2.68	0.00	0.00	-2.68	0.00	0.00	0.00	0.00	2.68	0.00	0.00	2.68
DM	2.68	0.00	0.00	1.34	1.34	0.00	0.00	-1.34	-1.34	0.00	0.00	-2.68
COM	0.00	1.34	0.67	0.00	0.00	0.67	-0.67	0.00	0.00	-0.67	-1.34	0.00
DM	0.00	-1.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00
COM	-0.50	0.00	0.00	-0.50	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.50
DM	0.50	0.00	0.00	0.25	0.25	0.00	0.00	-0.25	-0.25	0.00	0.00	-0.50
COM	0.00	0.25	0.13	0.00	0.00	0.13	-0.13	0.00	0.00	-0.13	-0.25	0.00
DM	0.00	-0.19	-0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.19	0.00
COM	-0.09	0.00	0.00	-0.09	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.09
DM	0.09	0.00	0.00	0.05	0.05	0.00	0.00	-0.05	-0.05	0.00	0.00	-0.09
Moment	0.00	27.15	-27.15	19.76	-19.76	22.19	-22.19	19.76	-19.76	27.15	-27.15	0.00

Figure 2: A typical analysis sheet (MS Excel 2010)

The design sheet is the final sheet where design for flexure and shear is carried out based on the information on the preceding three pages (Figure 1 and 2). Maximum bending moments and shear force values computed in the analysis sheet are entered in the design sheet for bending and shear reinforcements to be designed respectively. The design of a typical section based on the information in each of the design information sheet, analysis sheet, envelope sheet and design sheets are presented in appendices. A typical section of the design sheet is shown in Figure 3.

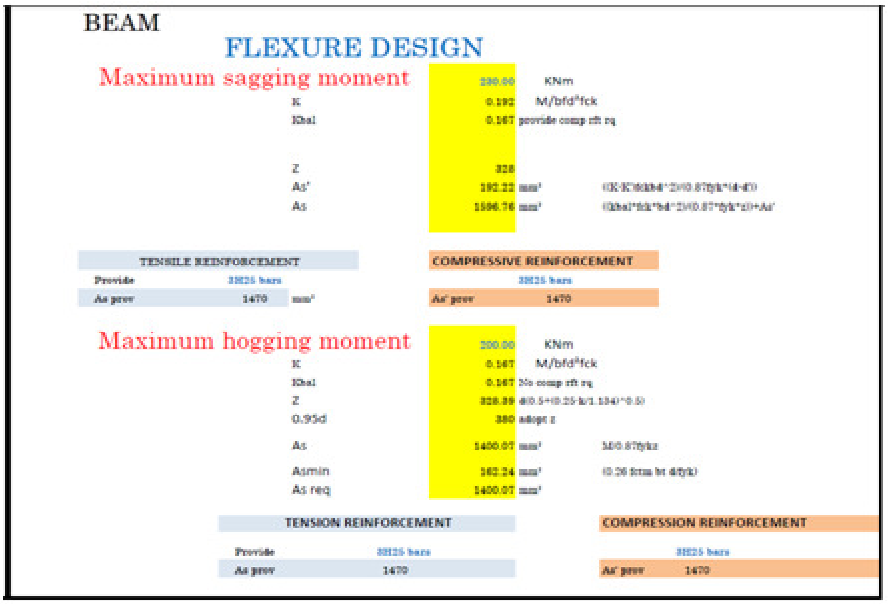


Figure 3: Design sheet (MS Excel 2010)

Deflection calculations are carried out in the worksheet in accordance to allowable and actual span-effective depth ratios as given in both codes of practice.

3.0 RESULTS AND DISCUSSION

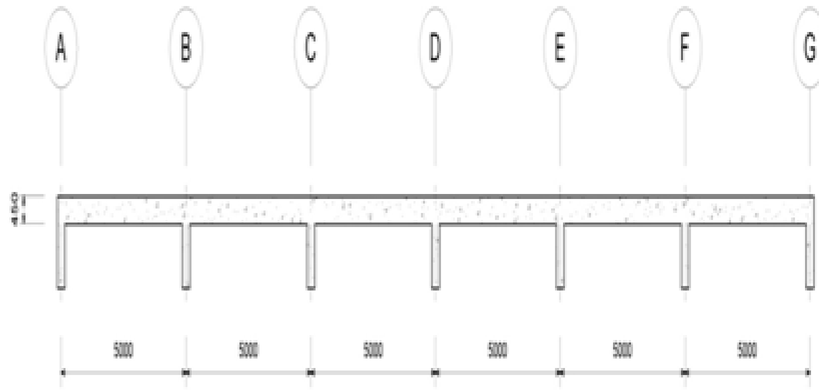


Figure 4: An example for numerical study

Comparison of Beam Analysis and Design Output

The results of the design and analysis for the beam according to BS 8110-1997 and Eurocode2 as determined automatically by the Excel program are as presented. To create a neutral base for comparison as regards bending moments and shear forces, the self-weight of the beam was taken as the dead load and a unit live load was considered for both cases. Table 2 shows the input data used in generating bending moments and shear forces along the beam.

Table 2: Input Data for Both Codes

Parameter	Eurocode 2	BS 8110
Concrete unit weight	25KN/m^3	24KN/m^3
Overall depth h	450mm	450mm
Width b	300mm	300mm
Live load Qk	1 KN/m	1 KN/m
Dead load Gk	25x450x300=3.375KN/m	24x450x300=3.24KN/m

Table 3: Comparison of moments along beam section

		Left support moment (KNm)			Maximum span moment (KNm)			Right support moment (KNm)		
span	**Length (m)**	**BS8110**	**Eurocode 2**	**% difference**	**BS8110**	**Eurocode 2**	**% difference**	**BS8110**	**Eurocode 2**	**% difference**
AB	5.0	0	0	0.00	-11.07	-10.92	-1.36	16.22	16.01	-1.30
BC	5.0	-16.22	-16.01	-1.30	-5.16	-5.10	-1.16	11.81	11.65	-1.35
CD	5.0	-11.81	-11.65	-1.35	-6.64	-6.56	-1.20	13.26	13.09	-1.28
DE	5.0	-13.26	-13.09	-1.28	-6.64	-6.56	-1.20	11.81	11.65	-1.35
EF	5.0	-11.81	-11.65	-1.35	-5.16	-5.10	-1.16	16.22	16.01	-1.30
FG	5.0	-16.22	-16.01	-1.30	-11.07	-10.92	-1.36	0	0	0.00
Average				**-1.10**			**-1.24**			**-1.10**

Table 4: Upper limit of shear force values for both Eurocode 2 and BS8110 at supports

		Shear at left support (KN)			Shear at right support (KN)		
Span	**Length (m)**	**Eurocode 2**	**BS8110**	**% difference**	**Eurocode 2**	**BS8110**	**% difference**
AB	5.0	11.94	12.10	-1.32	16.01	16.22	-1.29
BC	5.0	16.01	16.22	-1.29	14.85	15.05	-1.33
CD	5.0	14.85	15.05	-1.33	15.43	15.63	-1.28
DE	5.0	15.43	15.63	-1.28	14.27	14.46	-1.31
EF	5.0	14.27	14.46	-1.31	18.34	18.58	-1.29
FG	5.0	18.34	18.58	-1.29	0	0	0
Average				**-1.19**			

Table 5: Lower limit of shear force values for both Eurocode 2 and BS8110 at supports

		Shear at left support (KN)			Shear at right support (KN)		
Span	**Length (m)**	**Eurocode 2**	**BS8110**	**% diff.**	**Eurocode 2**	**BS8110**	**% difference**
AB	5.0	0	0	0	-18.34	-18.58	-1.29
BC	5.0	-18.34	-18.58	-1.29	-14.27	-14.46	-1.31
CD	5.0	-14.27	-14.46	-1.31	-15.43	-15.63	-1.28
DE	5.0	-15.43	-15.63	-1.28	-14.85	-15.05	-1.33
EF	5.0	-14.85	-15.05	-1.33	-16.01	-16.22	-1.29
FG	5.0	-16.01	-16.22	-1.29	-11.94	-12.10	-1.32
Average				**-1.19**			

Table 6: Percentage difference in area of Tension Steel Required for maximum span Moments

Span	**Length (m)**	**Maximum Span Moment (KNm)**	**As required (mm^2)**		**% difference**
			Eurocode 2	**BS 8110**	
AB	5.0	221.40	1540.91	1599.57	-3.67
BC	5.0	103.20	646.56	661.13	-2.20
CD	5.0	132.80	857.17	887.09	-3.37
DE	5.0	132.80	857.17	887.09	-3.37
EF	5.0	103.20	646.56	661.13	-2.20
FG	5.0	221.40	1540.91	1599.57	-3.67
Average					**-3.08**

Table 7: Percentage difference in area of Tension Steel Required for Maximum Support Moments

Support	**Distance from first outer support (m)**	**Max. Support Moment (KNm)**	**As required (mm^2)**		**% difference**
			Eurocode 2	**BS 8110**	
B	5.0	340.62	2315.12	2370.24	-2.33
C	10.0	248.01	1713.72	1771.59	-3.27
D	15.0	278.46	1911.46	1968.42	-2.89
E	20.0	248.01	1713.72	1771.59	-3.27
F	25.0	340.62	2315.12	2370.24	-2.33
Average					**-2.83**

Table 8: Percentage Difference In Shear Links Required Between Eurocode 2 and Bs8110

Support	Distance from first outer support (m)	Maximum shear force (KN)	A_{sv}/s_v		% Difference
			Eurocode 2	BS 8110	
A	0	181.50	0.463	1.064	-56.48
B	5.0	278.70	0.712	2.087	-65.88
C	10.0	225.75	0.577	1.529	-62.26
D	15.0	234.45	0.600	1.621	-62.99
Average					**-61.90**

DISCUSSION OF RESULTS

The percentage difference for bending moments between the two codes was calculated with the BS8110 values as controls. For the combination of dead and imposed loads considered, the average percentage difference for the span moments of the BS8110 exceeds that of the Eurocode2 by 1.24%, while the average support moments for the BS8110 exceeds those of the Eurocode2 by 1.10%.

In the case of shear force, the average percentage difference for the BS8110 exceeds that of the Eurocode2 by 1.19% for both upper and lower limits of shear force.

The percentage difference between the areas of steel required by the two codes was calculated with the BS8110 used as the control. For the values of moments considered, the average percentage difference of the area of tension reinforcements required for spans and supports are about 3.08% and 2.83% respectively.

The average percentage difference between the ratios Asv/S_v for shear links required by the two codes was estimated with the BS8110 exceeding the Eurocode2 by an average of 61.9%.

This difference in trend is attributed to the disparity in the design models adopted by both codes in determining the design loads. In BS 8110, design loads are determined by considering the formula given in equation 1 as opposed to the formula given in equation 2 for Eurocode2.

The BS8110 code applies larger partial safety factors to loads at the ultimate limit state in contrast to Eurocode2. For the Eurocode2, the partial safety factor with respect to dead loads is marginally lower compared with the BS8110 value.

4.0 CONCLUSIONS

The results of the comparative study led to the following conclusions:

(i) The BS8110 moments exceeds that of the Eurocode2 by an average of about 1.24% at spans and 1.10% at supports.

(ii) The shear forces at supports for the BS8110 exceeds that of the Eurocode2 by an average of about 1.19% for both upper and lower limits of shear force.

(iii) The Eurocode2 is more conservative in terms of the partial factors of safety for loadings. For a combination of live and dead load considered in this study, the BS8110 required about 1.3% more of the ultimate design loads than that of the Eurocode2.

(iv) The BS8110 requires more area of tension reinforcements at spans and at supports for continuous beams compared to the Eurocode 2. The BS8110 exceeds that of the Eurocode 2 by an average of about 3.08% for area of tension reinforcements for spans and 2.83% for supports.

(v) Taking into consideration the percentage of shear reinforcements required, the BS8110 exceeds that of Eurocode 2 by an average of about 61.90%.

(vi) Eurocode 2 provided a more economical design with the required margin of safety.

REFERENCES

1. British Standard Institute, (1997). Structural use of concrete-Part 1: Code of practice for design and construction.
2. Bond A. J. (2006). How to Design Concrete Structures using Eurocode 2.
3. European Union, (2004). Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings.
4. Jawad A.A. (2006). Strength design requirements of ACI-318M-02 Code, BS8110, and EuroCode2 for structural concrete: A comparative Study. Journal of Engineering and Development, 10(1), 22-28.
5. Kamarul, A. (2010). Comparison of slab design between BS 8110 and Eurocode 2 by using Microsoft excel.
6. Liew Y. H. (2009). British standard (BS 8110) and Eurocode 2 (EC2) for reinforced concrete column design. University of Technology Malaysia. Microsoft incorporation (2010). Microsoft Excel.
7. Moss, R.M. and R. Webster, (2004). EC2 and BS8110 compared. In: The Structural Engineer, Vol. 82, No. 6. Retrieved 20th January 2015 from: http://www.istructe.org/thestructuralengineer/hc/Abstract.asp?PID=805
8. Shodolapo O. F. & Kenneth K. M. (2011). A comparative study of EC2 and BS8110 beam analysis and design in a reinforced concrete four storey building. Journal of Basic and Applied Scientific Research, 1(12), 3172-3181.
9. Oyenuga, V.O. (2011). Reinforced Concrete Design-a consultant/computer based approach 2nd edition, Astro Limited, Lagos Nigeria.
10. Mosley, B., J. Bungey & R. Hulse, (2007). Reinforced Concrete Design sixth Edition.
11. O'Brien, E.J. and A.S. Dixon, (1995). Reinforced and Prestressed Concrete Design – The Complete Process, 1st Edition. Longman Scientific and Technical, United Kingdom, 492 pp.
12. Prerna Nautiyal, Saurabh Singh and Geeta Batham, "A Comparative Study of The Effect of Infill Walls on Seismic Performance of Reinforced Concrete Buildings" International Journal of Civil Engineering & Technology (IJCIET), Volume4, Issue 4, 2013, pp. 208 - 218, ISSN Print: 0976 – 6308, ISSN Online: 0976 – 6316.
13. N. Umamaheswari and Dhanya Mary Alexander, "A State of The Art Report on Fatigue Behaviour of Steel Structures Strengthened with Fibre-Reinforced Polymer Composites" International Journal of Civil Engineering & Technology (IJCIET), Volume 5, Issue 3, 2014, pp. 301 - 307, ISSN Print: 0976 – 6308, ISSN Online: 0976 – 6316.
14. S.R.Debbarma and S.Saha, "An Experimental Study on Growth of Time-Dependent Strain In Shape Memory Alloy Reinforced Concrete Beams And Slabs" International Journal of Civil Engineering & Technology (IJCIET), Volume 3, Issue 2, 2012, pp. 108 - 122, ISSN Print: 0976 – 6308, ISSN Online: 0976 – 6316.
15. R. M. Sawant, Junaid Khan, Jabeen Khan and Satish Waykar, "Behavior of High Strength Fiber Reinforced Concrete Under Shear" International Journal of Civil Engineering & Technology (IJCIET), Volume 6, Issue 4, 2015, pp. 46 - 54, ISSN Print: 0976 – 6308, ISSN Online: 0976 – 6316.